Draft Report to the Legislature

Quantifying the Efficiency of Agricultural Water Use

Department of Water Resources

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Introduction

The Department of Water Resources (DWR) has been directed by the Legislature upon enacting Section 10608.64 of the California Water Code to "*develop a methodology for quantifying the efficiency of agricultural water use.*" This report, prepared by DWR for the Legislature, provides legislators, public interests, and agricultural and other stakeholders with a methodology for quantifying the efficiency of agricultural water use. The report improves the understanding of agricultural water use and provides illustrative examples to demonstrate the complexity of quantifying the efficiency of agricultural water use.

During development of the methodology, two overriding concerns needed to be addressed by DWR to help focus development efforts. These concerns included: 1) historically varied interpretations and applications of the term "efficiency" when addressing agricultural water use, and 2) a clear understanding of the entity(ies) responsible for implementing the identified methodology to appropriately address issues of data availability, applicability, and long-term implementation. The following are defined:[rewrite the introduction include statute directive, process, approach, presentation of report, purpose for this report (wue)

1. Recognizing the complexities of defining "efficiency," the methodology should rather focus to establish a standard set of water use terms, equations relating these terms, and circumstances that define the applicability of the equations – collectively referred to in this Report as "methods" and "indicators".
2. An implementation plan should be developed with the intention that the standard methods and technical assistance be provided by DWR, with implementation primarily carried out by DWR and agricultural water suppliers, in cooperation with other state and federal agencies, non-profit organizations, universities, and research institutions. Implementation at the field level will occur voluntarily with the express cooperation of individual land-owners and growers.

This report is organized with the following primary sections:

1. Purpose of quantification – DWR provides a discussion and introduces a broad purpose to guide development of a methodology. This section also frames plausible approaches and presents the geographic boundary conditions proposed by DWR.
2. Water management methods – a discussion of the water management approach and the methods developed to quantify the efficiency of agricultural water use, including examples calculation of water management methods.
3. Productivity indicators – a discussion of the productivity approach and the indicators developed to evaluate the efficiency of agricultural water use for crop production, including example calculation of the productivity and crop value indicators.
4. Implementing the methodology – a plan for implementation and the estimated cost of implementation, accompanied by a discussion of data needs and limitations.

2.1 Purpose of Quantification

An important step to develop a methodology to quantify the efficiency of agricultural water use is to define the purpose. There are many methods to calculate relationships among various aspects of agricultural water use, such as geographic scale and the various agricultural water uses. The method(s) vary depending upon what the calculation is attempting to quantify. Therefore, selection of a method is dependent upon the purpose of quantification. This section provides further context to understand the elements of agricultural water use and methods to evaluate agricultural water use relationships. (rewrite to better describe what the methodology can be used for)

DWR prepared the following broad purpose statement to guide the development of a methodology based on policy statements and other language in the California Water Code (CWC) §10608 and input from stakeholders (more specific purposes for each method are provided as examples later in this Report). The legislation recognized the importance of water use efficiency for many purposes including water supply reliability, reducing demand on the Delta, energy and environmental benefits, managing the state water resources to meet the population growth, and managing for climate change challenges. It also recognizes the importance of supporting California's agriculture. With these recognitions in mind, DWR has defined the following as the broad purpose that enabled selection of a methodology:

> *Establish a methodology for water managers and those interested in the management of water resources – whether farmer, water supplier, advocacy group, or regional, state or federal planner or policy-maker – to evaluate current and potential water management paradigms and opportunities for modification in the management, distribution, and efficient use of water in agriculture.*

2.2 Legislative Direction and Declarations from Senate Bill x7-7 (the statutes of 2009)

Quantifying the efficiency of agricultural water use was directed by policy statements and other language in the 2009 legislation – SB x7-7. Specifically, §10608.64 of the Act states:

> *The Department… shall develop a methodology for quantifying the efficiency of agricultural water use.*
>
> *… the Department shall report to the Legislature on a proposed methodology and a plan for implementation. The plan shall include the estimated implementation costs and the types of data needed to support the methodology.*

Direction concerning methodological approach is also included in the Act.

> *Alternatives to be assessed shall include, but not be limited to, determination of efficiency levels based on crop type or irrigation system distribution uniformity.*

DWR identified further legislative direction in *Chapter 1, General Declarations and Policy* of the 2009 legislation. This chapter provided guidance in the assessment of methodology and development of an implementation plan for quantifying efficiency of agricultural water use that included the followings:

> *§10608. The Legislature finds and declares all of the following:*
>
> *(a) Water is a public resource that the California Constitution protects against waste and unreasonable use.*
>
> *(b) Growing population, climate change, and the need to protect and grow California's economy while protecting and restoring our fish and wildlife habitats make it essential that the state manage its water resources as efficiently as possible.*
>
> *(c) Diverse regional water supply portfolios will increase water supply reliability and reduce dependence on the Delta.*

(d) Reduced water use through conservation provides significant energy and environmental benefits, and can help protect water quality, improve streamflows, and reduce greenhouse gas emissions.

(e) The success of state and local water conservation programs to increase efficiency of water use is best determined on the basis of measurable outcomes related to water use or efficiency.

(f) Improvements in technology and management practices offer the potential for increasing water efficiency in California over time, providing an essential water management tool to meet the need for water for urban, agricultural, and environmental uses.

§10608.4. It is the intent of the Legislature, by the enactment of this part, to do all of the following:

(a) Require all water suppliers to increase the efficiency of use of this essential resource.

(e) Establish consistent water use efficiency planning and implementation standards for urban water suppliers and agricultural water suppliers.

(i) Require implementation of specified efficient water management practices for agricultural water suppliers.

(j) Support the economic productivity of California's agricultural, commercial, and industrial sectors.

(k) Advance regional water resources management.

§10608.8.

(c) This part does not require a reduction in the total water used in the agricultural or urban sectors, because other factors, including, but not limited to, changes in agricultural economics or population growth may have greater effects on water use. This part does not limit the economic productivity of California's agricultural, commercial, or industrial sectors.

§10800

(e) There is a great amount of reuse of delivered water, both inside and outside the water service areas.

(f) Significant noncrop beneficial uses are associated with agricultural water use, including streamflows and wildlife habitat.

(h) Changes in water management practices should be carefully planned and implemented to minimize adverse effects on other beneficial uses currently being served.

2.3 Quantifying the Efficiency of Agricultural Water Use

Rewrite this section. What is efficiency? How is efficiency defined? What do the different methods of efficiency provide as outcomes? Include definitions section?

To be efficient means to achieve a desired outcome with a minimum of waste. Efficiency, therefore, is a measure of how closely a process has achieved the desired outcome when considering the use of inputs necessary to achieve the outcome. Efficiency can be defined as a ratio that indicates the level of results achieved relative to the level of effort.

This methodology is focused on the use of water for irrigated crops only[1]. Two general approaches have been considered for quantifying the efficiency of water use associated with irrigated agriculture. edit

1. Water Management Methods that incorporate elements of water input (surface or groundwater, precipitation) and output (evapotranspiration, leaching, climate control, environmental needs) in the

[1] This methodology purposefully excludes specific methods to evaluate water use for agricultural processing and livestock operations, two important facets of agriculture that use water, but with far less water use than irrigated agriculture. Additionally, these agricultural operations have unique water use elements and "water in" and "water out" elements.

equations for evaluating water use efficiency. Include more general write up to describe water management efficiency methods (outputs/inputs)

2. Comparison of agricultural production and its value to the applied water. The input is measured in units of water volume and the output is measured in total yield or value of the crop commodity produced.

Discussion of water use efficiency has often focused on the field level irrigation efficiency only, evaluating the relationship between applied water (often denoted AW) and the ET of that applied water (denoted ETAW). However, this definition does not account for other elements associated with the delivery and application of water to produce the desired agricultural commodity. Water may flow into another boundary (water supplier) or percolate into groundwater in the region or may meet environmental objectives beyond the region. Water may also percolate into unusable groundwater or to salt sinks. Therefore discussion and quantification of water use efficiency from water management perspective need to recognize the fate of all aspects of water within a defined water balance framework.

Other definitions of agricultural water use efficiency include considering farm crop production or revenue in relation to the applied water (Cooley, et al. 2009). DWR defines agricultural water use efficiency in the Water Plan Update (DWR, 2009) as "the ratio of applied water to the amount of water required to sustain agricultural productivity."

In order to consider all factors associated with the delivery and application of water for agricultural productivity, the efficiency of agricultural water use may appropriately be quantified using different methods and indicators under different circumstances.

2.3.1 Methodology

As defined by Merriam-Webster Dictionary (on-line version), the term methodology is defined as:

- *A body of methods, rules, and postulates employed by a discipline: a particular procedure or set of procedures*.

Whereas the term "method" is defined as:

- A procedure or process for attaining an object: as a way, technique, or process of or for doing something: a body of skills or techniques.

Using these definitions of methodology and the approaches to quantify efficiency, the methodology for quantifying the efficiency of agricultural water use is a set of procedures, called methods, to evaluate specific ratios of water use and production data within different geographic scales. In other words, several methods are used to calculate efficiency of agricultural water use at a particular defined geographic boundary.

Defining a methodology in this manner allows establishing a common set of methods to provide information that can be used by a farmer, water supplier, advocate, or policy maker for a number of objectives including:

- Provide a foundation to support other goals, including: understanding the benefits and limitations of current systems and management practices, and evaluating the benefits and limitations of changes to current systems and management practices.
- Maintain or improve the management of water for an array of defined objectives including water conservation, energy and environmental benefits, water quality protection and greenhouse gas emission reduction.
- Guide projects, programs, and policies at local, regional, and state scales to improve the efficiency of agricultural water use.

2.3.1.1 Water Management Approach

One approach for quantifying the efficiency of agricultural water use is to focus on the elements of a water balance (e.g. water brought onto a field, water consumed by the crop, water used to meet agronomic needs, water flowing out of the boundary of the field, etc.). As illustrated in a generic format in Figure 2-1, a water balance is a representation of all sources and dispositions of water into, within, and out of a defined boundary. From these water flow elements, various relationships can be evaluated to describe the current water management conditions and assess opportunities for change.

In the generic balance in Figure 2-1, the boundary condition represents a water supplier, but illustrates several sub-boundaries within. However, since hydrologic, regulatory, distribution, and other features reflected in a water balance are unique to the specific boundary being evaluated, each water balance can look different from another. To illustrate this, consider the graphical representations of water balances for two unique water suppliers: the Imperial Irrigation District in the southeast corner of the State (see Figure 2-2) and a Sacramento Valley water district (see Figure 2-3). Each of these balances reflects the unique circumstances faced by each water supplier, but include common elements that allow for relationships between different "water in" and "water out" components to be evaluated.

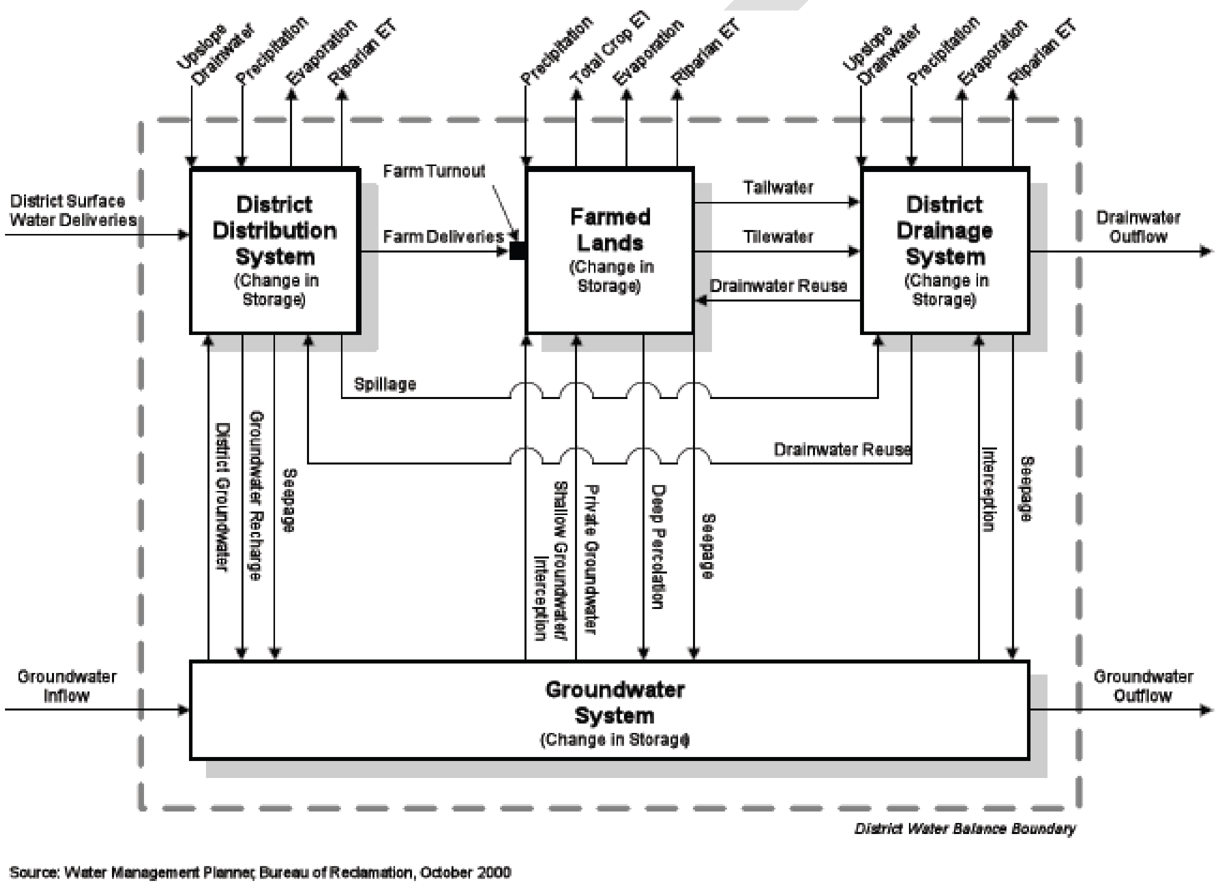

FIGURE 2-1
Generic Water Balance – Developed for the Bureau of Reclamation's Water Management Planner in 2000
Quantifying the Efficiency of Agricultural Water Use

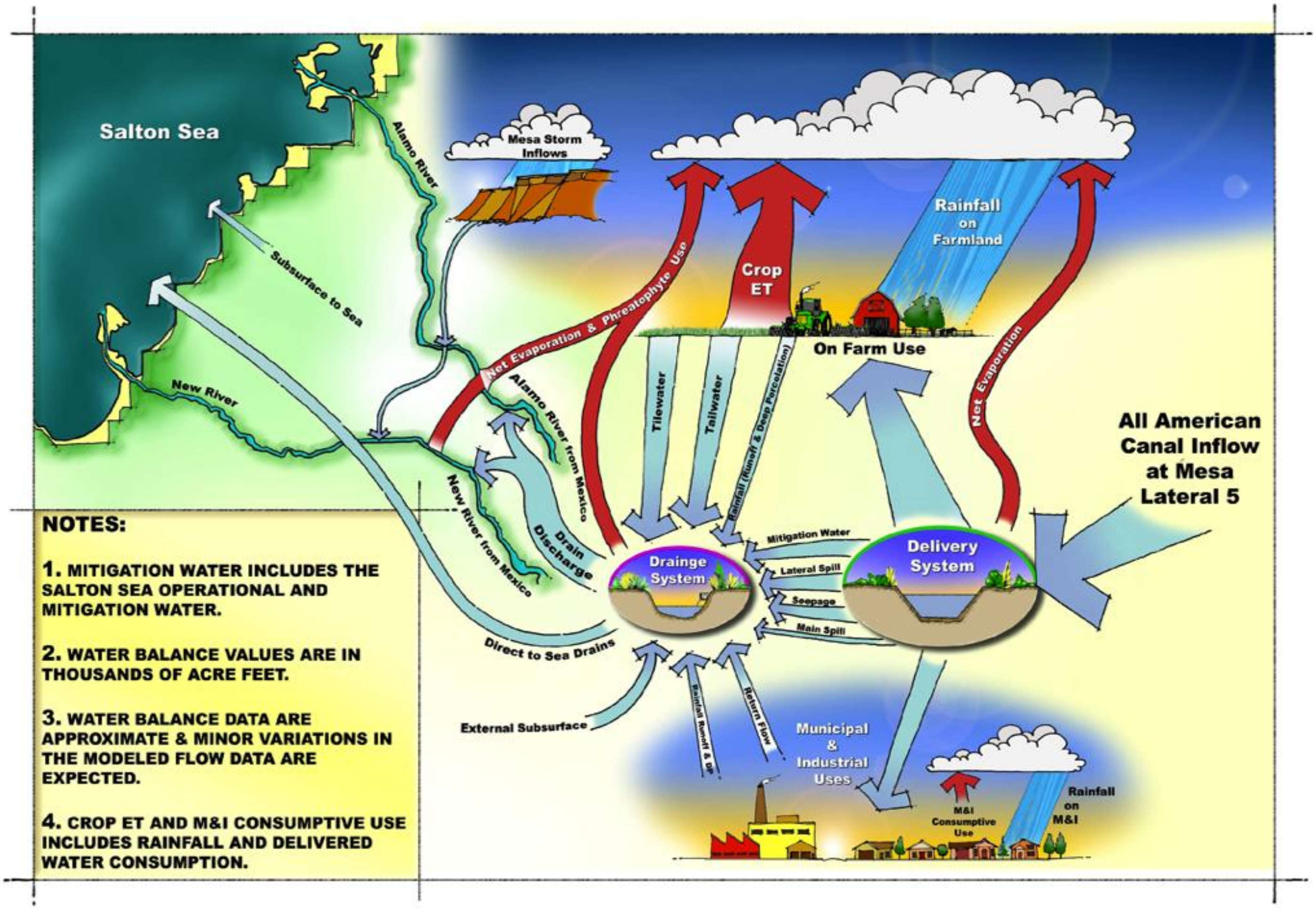

FIGURE 2-2
Example of a Water Balance – Imperial Irrigation District
Quantifying the Efficiency of Agricultural Water Use

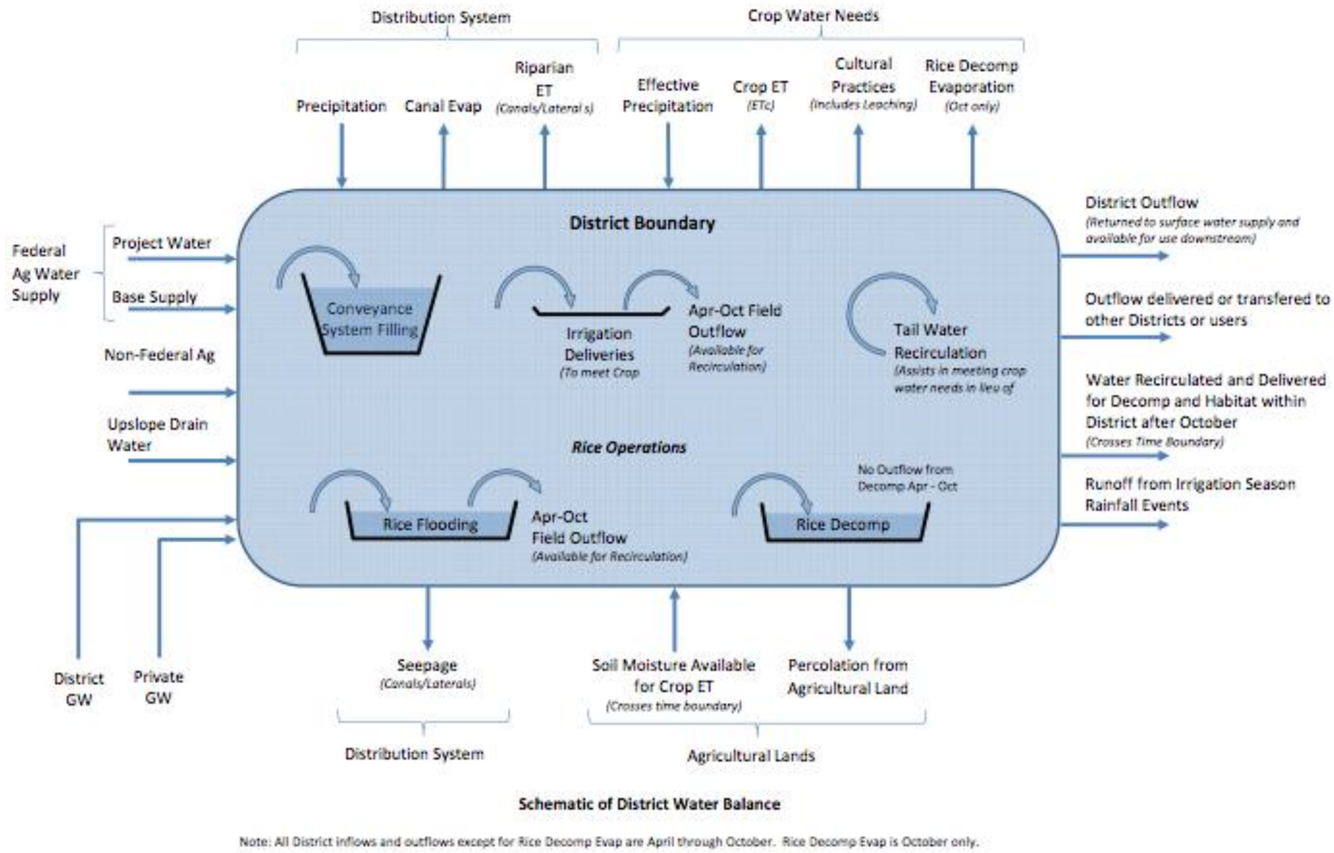

FIGURE 2-3
Example of a Water Balance – Sacramento Valley Water Supplier
Quantifying the Efficiency of Agricultural Water Use

When viewing the water balance from different water management and use boundary conditions – the field, the water supplier, or the region – a different set of “water in” and “water out” conditions exists. Because of this variability, understanding all components of a water balance and their relationships within a defined boundary is fundamental to understanding the efficiency of the water used. Furthermore, given the multiple flow paths into and out of a boundary, differing sets of ins and outs can be related through equations to evaluate current water management and use conditions. This also means that there is no single equation to represent the efficiency of agricultural water use.

For purposes of developing a methodology, DWR developed three primary water management boundary conditions that most closely align with crops, delivery systems, and water management. These are: Field, Water Supplier, and DWR Hydrologic Region scale.

Field

The field scale, a term used to define the boundary of a parcel of land served by an irrigation method or system, allows an assessment of a variety of attributes associated with irrigation system(s) and management within a field. Field scale assessments allow an operator to evaluate the performance of an individual irrigation system for a particular crop at a particular point in time or across a defined time period, such as a growing season. This assessment will allow an operator to measure the effectiveness of the existing irrigation system to meet the water needs of the crop.

In some cases, more than one field is irrigated from the same turnout. If all fields are using the same kind of irrigation system to irrigate the same crop, the group of fields can be measured as one field. If the individual fields are growing different crops or using different kinds of irrigation systems, they should not be grouped into a single measurement. If the field-level efficiency is to be quantified for one or more such fields, additional effort is required to measure or estimate the water delivered to each of the fields.

Water Supplier

The water supplier scale allows an assessment of a variety of attributes associated with the operations and management of a water delivery system within the defined service area of a water supplier. The goal of an agricultural water supplier is to use infrastructure and management (e.g., operations or pricing) to efficiently and reliably deliver available water supplies to the field scale irrigation systems. Information regarding water flows in this scale allows for evaluation of the relation between water brought into the boundaries and the effectiveness of meeting the primary goal of delivering water to the fields.

DWR Hydrologic Region

The DWR Hydrologic Region (regional) scale allows an assessment of a variety of attributes associated with regional water use and management within the regional boundary. For purposes of defining a methodology at this scale, one prominent use would be the California Water Plan Update (Update). In the Update, DWR gathers and assesses information at a regional boundary called the Detailed Analysis Unit (DAU). DWR then aggregates the information to larger regional boundaries, the Hydrologic Region, and the State as a whole.

2.3.1.2 Productivity Approach

The productivity approach indicates output of crop production to the input of water use in agricultural production, measured as either physical output or the dollar value of output per unit volume of water. Examples of this approach generally relate elements such as (1) productivity – the ratio of tons of crop produced to the volume of water applied, or (2) value of production – the ratio of gross crop revenue received for a commodity to the volume of water applied for producing it.

The crop productivity and value of production are functions of several significant factors in addition to the quantity of water used. Specifically, productivity and value of production, even for the same crop, vary among regions and over time for reasons unrelated to water use. Crop varieties, pest infestations, weather, and crop market shifts are only a few of the factors that have a large influence on crop productivity and value of production. Therefore, crop productivity and the value of production calculated are indicators of efficiency of water use for crop production but they do not represent the true magnitude of crop productivity and value of production as a function of unit of water, because of the effects of all the other un-quantified production and market variables. The crop productivity method and calculate of production method will be referred to as "productivity indicators" and "value of production indicator", hereafter.

The productivity indicator is calculated by dividing the weight of crop production at any given scale to the volume of water applied to that scale. There are two ways to measure of the value of production indicator or crop value per unit of water use. The first is inflation-adjusted dollars of gross agricultural revenue per acre-foot of applied water. An analysis in Volume 4 of DWR's California Water Plan Update 2009 used this measure to illustrate the increasing economic productivity of California agricultural water use:

> "The rising real value of our agricultural output, coupled with falling crop water use, has more than doubled the "economic efficiency" of agricultural water use in California during the past 40 years. In 1967 there was $638 (in 2007 dollars) of gross agricultural revenue produced in California for each acre-foot of applied water. By 2007 this measure had risen to $1,373/AF. That represents a 115 percent increase in 40 years."

The second measure is the same as the above measure, except that acre-feet of ETAW would be used, instead of acre-feet of applied water. This is a less useful indicator of the efficiency of agricultural water use, because it removes from the calculation all water quantities that might be characterized as inefficient. To illustrate, consider two identical fields with identical crop, yield, value, and ETAW, but one field received 20% more applied water, which percolated to a saline aquifer. Those fields would have the same ETAW and therefore the same productivity and the same value of production.

The productivity and value of production ratios described above should not be viewed as measuring economic efficiency in the way that economists define the term “economic efficiency”. In general, economic efficiency is not a single, quantifiable value that is measurable on an absolute or relative scale, but rather is a set of conditions relating input use and output. The ratios described above are productivity indicators that relate to, but are not the same as, the economic efficiency of agricultural water use, and which can illustrate broad comparisons between regions or crops or over time. These indicators may be used to help guide public policy and public investment, but with an understanding of their limitations.

The productivity approach indicators are proposed for three scales: field, county, and statewide.

Water Management Methodology for Quantifying the Efficiency of Agricultural Water Use

A number of methods and associated procedures to quantify the efficiency of agricultural water use have been developed. The set of methods and procedures are intended to evaluate the efficiency of agricultural water use for different purposes at different scales. These methods are:

- Water management methods applicable at the field, water supplier, and regional scale:
    - Consumptive Use Fraction
    - Agronomic Beneficial Use Fraction
    - Total Beneficial Use Fraction
- Water management methods applicable at only the field scale:
    - Distribution Uniformity
- Water management methods applicable at the water supplier and regional scale only:
    - Delivery Fraction
    - Water Management Fraction

This section describes each method in detail. The appropriate elements used to calculate the methods are identified and the purpose and examples of each method are provided at each applicable geographic scale.

3.1 Water Balance Components

As specified in Section 2.3.2, a primary approach for quantifying the efficiency of agricultural water use is through evaluating the relationship of particular components of the water balance. These relationships may include volume of water use attributed to ET, leaching, frost protection, and other agronomic and environmental beneficial uses compared to the volume of applied water. The water management approach evaluates the efficiency of water applied to a specific area, intended for irrigated agriculture and environmental objectives.

Components of a water balance are used in the water management approach methods for quantifying the efficiency of agricultural water use. These components are: make consistent Water Plan Update

1. *Agronomic needs* = the portion of applied water directed to help produce the desired agricultural commodity, such as water applied for salinity management or frost control, decomposition, and other water applications essential for production of crops. The quantity of applied water estimated for intended agronomic needs is based on accepted professional practices.
2. *Environmental needs* = the additional portion of applied water directed to environmental purposes, such as water for wetland, riparian or terrestrial habitat. The quantity of applied water estimated for intended environmental needs is based on accepted professional practices.
3. *Evapotranspiration of Applied Water (ETAW)* = Total crop evapotranspiration needs minus estimated quantity of effective precipitation. Crop evapotranspiration is the water transpired from the crop surface and the evaporation of water from the soil surface surrounding the plants. Effective precipitation is that portin of precipitation that is stored in the soil profile to meet crop's irrigation needs.
4. *Recoverable Flows* = the estimated or measured quantity of water leaving the defined scale as either surface flows or percolation to underlying useable aquifers.

5. *Applied Water* = the total amount of water that is diverted from any source to meet the demands of water users without adjusting for water that is used up, returned to the developed supply and irrecoverable flows (unproductive evaporation or percolation to salt sinks) .

6. *Irrecoverable Flows= the estimated quantity of water leaving the defined scale boundary as either surface flows, unproductive evaporation or deep percolation to salt sinks. The irrecoverable flows are not estimated in this methodology.*

Non-irrigation agricultural water use is not considered in the water management approach when quantifying the efficiency of agricultural water use. Non-irrigation agriculture could include dairies, on-farm processing, or other agricultural operations that are not specifically related to irrigated land. While any irrigated agricultural practices on such operations would be included when quantifying the efficiency of agricultural water use, a methodology for quantifying the efficiency of water used for non-irrigation agriculture is not included in this report.

3.2 Methods

Collectively, the methods listed above provide valuable information to the local users, associated agricultural water suppliers, and to the extent methods are reported beyond the field or supplier scale, they also provide insight and understanding to regional, state and federal policy makers. The following agricultural water use efficiency methods are applicable at each of the three identified scales (the input data will vary by scale):

- Method 1: Consumptive Use Fraction (CUF) – This method allows for evaluation of the relationship between the consumptive use of a crop and the quantity of water brought into the boundary. The numerator of the equation would be the measured or estimated crop consumption of water applied at the field scale (ETAW or Evapotranspiration of Applied Water), and the denominator would be the quantity of water brought into the boundary. CUF= ETAW/AW. At the fields scale, the denominator would be the quantity of applied water, consisting of deliveries at the field scale and/or water pumped or diverted onto the field. At the supplier or regional scale, the denominator would be the applied water delivered to the boundary of the supplier or region and all pumping for irrigation use within the supplier or the regional boundary, and the numerator would represent the aggregated ETAW of the crops grown within the boundary.

- Method 2: Agronomic Beneficial Use Fraction (BUF_A) –This method builds upon the CUF to add agronomic water (see definition under Section 3.1) to account for the quantity of water reasonably applied, at the field, water supplier, or Regional scales to help meet the total water needs associated with the production of the crop(s). This provides a method to evaluate the relationship between the water for crop consumptive use and the quantity of water that is necessary to produce a crop. Agronomic needs (AN) are the quantity of water needed for salinity management and the portion of frost control water that is not consumed by the crop. Therefore, only the portion of the agronomic water that is not consumed by the crop can be added into the numerator. ABUF= (ETAW+AN)/(AW), where AN is the agronomic needs. For instance, with water used to leach salts, the portion of water applied to push salts below the root zone would be considered the additional water needed to grow the crop. In contrast, some of the water applied for an agronomic need such as frost control might refill the root zone and ultimately be consumed by the crop. Only some of the frost control application would be considered additional agronomic use (i.e., the net agronomic water from an application of water for frost control would be less than the total applied for frost control). [describe how the net agronomic needs is determined/estimated] At the water supplier or Regional scales, the known or estimated agronomic water use for all the crops grown within the boundary would be included – at the field scale, only the portion associated with that field's crop would be included. The term Agronomic Beneficial Use used in this report signifies the water that is expected to benefit crop production because it meets its production needs. While ideally one intends to supply sufficient water to meet the agronomic needs, in practice such ideal goal is not possible under the variable field conditions. In other words, the practice of applying water to meet crop agronomic needs may have water losses beyond the agronomic needs. Therefore, the term "Beneficial Use" used in this report should not be considered equivalent to the "Beneficial Use" used for water quality or water rights purposes.

- Method 3: Total Beneficial Use Fraction (BUF_T) – This method further expands the CUF and the BUF_A to include environmental water (see definition under Section 3.1) to account for the applied water at the field, water supplier, or Regional scale. The additional water must be intended to meet environmental objectives. Potential objectives may include flooding fields to support migratory birds or providing water to maintain riparian vegetation, or ponds to support other desired species. At the water supplier or regional level, environmental water use may include water intentionally directed to drains to support riparian habitats, and maintenance of delivery system vegetation as may be planted and maintained on delivery canal banks. TBUF= (ETAW+ AN+ EN)/(AW), where EN is environmental water use. For this method, the denominator remains the quantity of water brought into the boundary, but the additional water directed toward intended environmental objectives is added to the numerator. Only additional water beyond what already meets crop consumptive and agronomic needs as defined in Method 2 should be counted.

Importantly, these methods cannot be viewed independently from one another. Each method provides a unique understanding of the performance of agricultural water use at a defined scale. In fact, using these methods in tandem allows for not only quantifying each water use fraction separately, but also comparing the proportions of water used for different purposes (e.g., consumptive use, agronomic use, etc.). Such comparisons will in turn allow identifying areas of inefficiency and informed water management decisions in relation to adopting potential management alternatives (e.g., modifying irrigation systems or proceeding with a mechanical rice straw stomping versus field flooding).

In addition to the above three primary methods that are applicable at all water management scales, methods 4 and 5 are applicable to only the water supplier and regional scales and method 6 is applicable to field scale only:

- Method 4: Delivery Fraction (DF) – This method allows the evaluation of the relationship between the water delivered to irrigated agriculture (e.g. fields) in a defined boundary to the total surface or groundwater water brought into the boundary. Under California Water Code §531.10, many water suppliers are required to provide DWR with aggregated farm-gate deliveries. When water delivered to irrigated agriculture is related to the total water brought into the boundary, a better understanding of the supplier's or region's water delivery system can be obtained. In some instances, due in part to reuse occurring within the defined boundary, this fraction can exceed 100 percent. DF= (FGD)/(TWS), where FGD is the total farm-gate delivery and TWS is total surface and groundwater suppliers delivered or diverted into the boundary (water supplier or region).
- Method 5: Water Management Fraction (WMF) – This method provides an opportunity to recognize that a portion of water diverted by a water supplier or into a region but not used is recoverable flow (see definition under Section 3.1). The numerator in this equation would add both the consumptive use of the crops in the water supplier's boundary (or the Regional boundary) and the quantity of recoverable flow, which would be divided by the total water brought into the boundary. WMF= (ETAW+ RF)/(TWS), where RF is recoverable flow used in the supplier or region boundary or used in another supplier or region boundary. In regions where there is little recoverable flow (e.g. water exits the defined boundary to salt sinks or other degraded water bodies), the value would be closer to that evaluated under Method 1. Method 5 would be greater than Method 1 for regions where recoverable flows become later available water supply at a later time, or within another water supplier's boundary. This method allows for the recognition that unconsumed water is still available elsewhere or at another time within the water management system.
- Method 6: Distribution Uniformity (DU) – This method provides an opportunity to evaluate how effective an irrigation system is across an individual field for distributing the water. It indicates how evenly the water is applied across a field. To calculate DU, the numerator would be the average depth of the low quarter area of a field. The low quarter being the area of the field receiving the least amount of water relative to the entire field. The denominator would be the average depth for the entire field. DU=(Dawlq)/(Daw), where Dawlq is the average lower quarter depth of applied water and Daw is the average depth of applied water across the field. Although DU provides insight into irrigation system performance and opportunities to improve the application of irrigation water, it does not signify the appropriate quantity of water for a specific crop. DU is

generally calculated for an irrigation event. Although average of DU values over a year or between fields can be useful information for irrigation management.

3.3 Examples of Calculating Methods

Understanding the potential purposes at each scale provides insight into the development and use of the methodology developed in this report. To help understand the applicability of the methods, the following provides suggested purposes, coupled with a detailed example of calculating the various methods.

3.3.1 Field Scale

3.3.1.1 Purposes

Drawing directly from policy statements and other language in the enabling legislation, several purposes have been identified to define purposes for evaluating agricultural water use at the field scale. These include:

1. Determine the relationship between the amount of water applied to a field and that being consumed by the crop.
2. Determine how uniformly water is applied across a field.
3. Quantify how water applied for irrigation, agronomic and environmental uses affects field scale efficiency of agricultural water use.
4. Assess opportunities to reduce applied water while still enabling crop productivity and intended environmental benefits.
5. Assess the performance of irrigation and water management methods by comparing fractions among fields growing similar crops under similar conditions (e.g. same soils, water quality, and supply reliability).
6. The water management methods for the field scale when applied to individual fields only demonstrate the water management for the specific irrigation event for the specific location or the water management condition for the specific filed during a season, it does not represent the water management condition at a larger scale, region or statewide. However, because of importance of water management at the point of use is critical to achieving statewide efficient use of this resource; it is included in the methodology.

3.3.1.2 Examples

To provide insight into the use of the five primary methods at the field scale, the following example was developed. Under this example, the field consists of 125 acres of processing tomatoes; planted from seed in raised beds and furrow irrigated. The field scale deliveries are augmented with groundwater pumping and the net change in surface storage and soil moisture are accounted for. Using this example for a single growing season, each method is calculated at the field scale in Table 3-1.

TABLE 3-1
Field Scale Example of Primary Agricultural Water Management Methods
Quantifying the Efficiency of Agricultural Water Use

Data Element	Calculation	Result
ETAW	Example Method 1 – ETo X Kc using CIMIS and available crop coefficients to estimate crop consumptive use (reference to be added, provide for other than CIMIS). This method assumes uniformity and subtracts estimate of effective precipitation from crop consumptive use (method of estimation to be added). ETAW, if calculated for one irrigation event, is the total ETAW from the date of previous irrigation.	Example Method 1 = 2 AF/ac = 250 AF per season
	Example Method 2 – field-specific analysis using remote sensing techniques that account for non-uniformity of crop response in a field due to varied soil, applied water or other conditions that change the ET of the plant compared to other areas of the field (and thus may	Example Method 2 = 235 AF per season (recognized that the field had areas where the plant was underperforming, resulting in less ETAW than ideal

TABLE 3-1
Field Scale Example of Primary Agricultural Water Management Methods
Quantifying the Efficiency of Agricultural Water Use

Data Element	Calculation	Result
	reduce ET).[provide guidance on how to use or delete method 2)	
Agronomic	Water and soil quality are good, so minimal leaching is assumed, leaching requirement is assumed based on accepted professional practices to be 5% of Etc(reference and formula to calculate LR to be added). Seed bed needs wetting to allow plant to break soil crust, adding another 2-inches or about 17 AF. This crop does not have frost control water needs, thus it is not included. If a crop needs frost protection the portion of the frost control water that will be consumed by crop should be subtracted from the frost control water use and the remainder included in agronomic need. (describe how net agronomic needs for frost control can be computed, provide guidance or reference)	LR = 12 AF per season Seed bed = 17 AF per season Total = 29 AF per season (*of this amount, 10 AF of the seed bed water also doubles as water for ETAW, which results in a net agronomic quantity of 19 AF*)
Environmental	Small wetland and garter snake habitat maintained on field edges; plants assumed to use water like a grass hay such as Sudan; approximately 5 acres of habitat (provide guidance on how to determine EN)	Habitat = 20 AF per season
Distributional Uniformity	Determine the average low quarter water depth of a field relative to the average depth of water applied to the entire field for one irrigation event.	Average low quarter depth = 2.8 inches per irrigation event Average applied water depth = 3.8 inches per irrigation event
Field Scale Applied Water	Estimate provided by water supplier in monthly measured deliveries if the entire delivery is applied to the field. Field level groundwater pumping and net change in surface storage and/or soil moisture accounted for. Alternatively, for field evaluation the applied water may be measured with a water measurement device.	373 AFAW per season 10 AF per season of private groundwater pumping 10 AF per season put to field scale surface storage 3 AF soil moisture in the field from previous season
Equations:		
DU	= 3.2/3.8	= 74%
CUF	= 250/373	= 67%
BUF_A	= (250+19)/373	= 72%
BUF_T	= (250+19+20)/373	= 77%

3.3.2 Water Supplier Scale

3.3.2.1 Purpose

Several purposes have been identified that draw directly from policy statements and other language in the enabling legislation that suggest the purposes to evaluate agricultural water use relationships at the water supplier scale, including:

1. Assess the relationship of the total quantity diverted into a water supplier boundary, including that pumped by the water suppliers and private entities, to the quantity actually consumed by the crops being grown.

2. Assess the total quantity diverted into the water supplier boundary to the needs of both crop and non-crop beneficial uses.
3. Assess opportunities to reduce the total quantity diverted into a water supplier boundary while still enabling crop productivity and intended environmental benefits by investigating the portion of water diverted that is not directly meeting crop and non-crop beneficial uses.
4. Compare the amount of water diverted or delivered to the supplier to the amount that the supplier delivers to the fields for crop production.

3.3.2.2 Examples

The following example was developed to provide insight into the use of the three primary methods at the water supplier scale. Under this example, a water supplier serves 45,000 acres of permanent and row crops irrigated with surface water and groundwater. The supplier operates groundwater wells, in addition private wells are used in some instances to supplement supplier deliveries. The supplier maintains one side of all delivery canals for habitat benefit. The supplier is required to maintain certain flows in long-standing drains to maintain beneficial riparian habitat. The supplier also provides water for livestock production and municipal and industrial users within its service area. Using this example, each method is calculated at the water supplier scale in Table 3-2.

TABLE 3-2
Water Supplier Scale Example of Primary and Secondary Agricultural Water Management Methods (see also table 3-1 for additional applicable details)
Quantifying the Efficiency of Agricultural Water Use

Element	Calculation	Result
ETAW	Example Method 1 – Using ETo and Kc data for general crop types, multiply all the crop acreages by the ETAW, derive a total ETAW, and subtract effective precipitation. Example Method 2 – Use processed satellite data to obtain total crop water use (this value is shown with a higher result to indicate that it is possible for micro-climates to exist that are not reflected in CIMIS or other ETo data, thus in this case the Method 1 estimate is low.)	Example Method 1 = 126,000 AF per year Example Method 2 = 134,300 AF per year
Agronomic	Each crop type has an assumed agronomic need, based on prior analysis and field investigations. Approximated at 7% of crop-specific ETAW per acre of crop (stakeholder and personal communication). The agronomic needs depend on many factors including crop type, climate, soil and water quality. Therefore, the agronomic needs are site specific and should be computed based on professional practices.	Approx = 9,000 AF per year
Environmental	Supplier - Garter snake habitat maintained on canal banks; plants assumed to use water like a grass hay such as Sudan (4 AF/ac); approximately 50 acres of habitat; Field – Several fields are flooded in fall/winter to provide habitat for migratory birds. Approx 6-inches per acre of net water for 8,000 acres in supplier's boundary are used Required to maintain 6 cfs flows down drain from June 1 through October 30 for habitat (approx. 12 AF/day)	Canal habitat = 200 AF per year Field habitat = 4,000 AF per year Drain flows = 1,800 AF per year
Aggregate Field Scale Applied Water	Estimate provided by water supplier in monthly measured billings. Field level groundwater pumping and net change in surface storage and/or soil moisture accounted for.	Aggregate Field Scale AW per year = 148,555
Recoverable Flows	This value is estimated using several different sources of data and calculations. First, data is obtained from gauge on the drain, which represented approx. 90% of the surface return flows.	Drain data = 1,800 AF per year Estimated deep percolation from leaching = 7,500 AF per year (2 inches per acre)

TABLE 3-2

Water Supplier Scale Example of Primary and Secondary Agricultural Water Management Methods (see also table 3-1 for additional applicable details)

Quantifying the Efficiency of Agricultural Water Use

Element	Calculation	Result
	Second, using information on delivered water quality and estimates of the portion of agronomic water used to leach salts, an estimate of deep percolation associated with beneficial agronomic uses is derived. Third, using the results of the $SBUF_T$ equation, the remaining portion of the total delivered water that is not crop ET, agronomic water or intended environmental water is identified. Of this, an estimate is made as to how much of this water evaporates or is used by non-crop plants that are not part of intentional environmental objectives. The portion remaining is considered returning as additional deep percolation to that from intentional leaching.	Estimated additional deep percolation (not from leaching) = Step 1 = 160,920-141,000 = 19,920 AF Step 2 = assume 20% of this evaporates from delivery system and/or is ET of incidental plants within Regional boundary. Step 3 = 80% (19,920) = 15,936 AF per year Total estimated recoverable flows = 1,800 + 7,500 + 15,936 = 25,236 AF per year
Supplier Scale Applied Water	The total quantity diverted by the supplier is derived from records maintained for filing to the SWRCB. The quantity of supplier and privately pumped groundwater is estimated from the change in groundwater elevation between spring and fall readings in several monitoring wells within the suppliers boundary combined with hydro-geological data from prior studies relating elevation change to volumes. Total deliveries to non-irrigation agriculture and M&I are subtracted from the total. Delivered water also excludes groundwater recharge and accounts for the net change in surface storage within the water supplier's boundaries.	Supplier diversions = 156,420 AF per year Estimated GW pumped = 19,500 AF per year Supplier non-irrigation agricultural deliveries = 10,000 AF per year Supplier M&I deliveries = 5,000 AF per year No groundwater recharge or net change in surface storage. Applied water per year = 160,920 AF per year
Equations:		
CUF	= 126,000/160,920	= 78%
BUF_A	= (126,000+9,000)/160,920	= 84%
BUF_T	= (126,000+9,000+6,000)/160,920	= 88%
DF	= (148,555)/160,920	= 92%
WMF	= (126,000+25,236)/160,920	= 94%

3.3.3 **DWR Hydrologic Region Scale**

3.3.3.1 Purposes

Drawing directly from policy statements and other language in the enabling legislation, several purposes are suggested that identified purposes for evaluating agricultural water use relationships at the regional scale, including:

1. Determine the relationship between the amount of water applied to fields within the region and that being consumed by the crops.
2. Determine the relationship between the total quantity of water diverted into a defined Regional boundary to that being consumed by the crops.
3. Quantify how water applied for agronomic and environmental uses affects regional scale efficiency of agricultural water use.

4. Assess opportunities to modify current water management systems and operations.
5. Compare field scale methods to the regional scale methods to assess effects of and opportunities for reuse and recoverable flows within and between regions.

3.3.3.2 Examples

To provide insight into the use of the three primary methods at the Regional scale, the following example was developed. Under this example, a regional scale represents the agricultural water use in a DAU in the Sacramento Valley. Note, several DAUs would comprise a DWR Hydrologic Region. The example DAU represents a mixture of permanent, row, and rice crops over 200,000 acres, and is primarily served with surface water from the Sacramento River diverted under several contracts and water rights. Groundwater is pumped for about 15% of the lands as a sole source and for about 20% as a back-up to surface supplies. The region is also home to a federal managed refuge. The aquifer is not actively managed, so the regional changes in storage would only include water stored in surface reservoirs within the regional boundary. However, the region does not have reservoirs within the boundaries. Using this example, each method is calculated at the regional scale in Table 3-3.

TABLE 3-3
Regional Scale Example of Primary and Secondary Agricultural Water Use Methods (see also table 3-1 for additional applicable details)
Quantifying the Efficiency of Agricultural Water Use

Data Element	Calculation	Result
ETAW	Example Method 1 – Using ETo and Kc data for general crop types, multiply all the crop acreages by the ETAW, derive a total ETAW, and subtract effective precipitation. Example Method 2 – Use processed satellite data to obtain total crop water use.	Example Method 1 = 795,000 AF per year Example Method 2 = 807,300 AF per year
Agronomic	Each crop type has an assumed agronomic need, based on prior analysis and field investigations. Approximated at 7% of crop-specific ETAW per acre of crop.	Approx = 62,000 AF per year
Environmental	Supplier - Garter snake habitat maintained on canal banks; plants assumed to use water like a grass hay such as Sudan (4 AF/ac); approximately 1,500 acres of habitat; Field – several fields are flooded in fall/winter to provide habitat for migratory birds. Approx 6-inches per acre of net water for 60,000 acres in region's boundary are used. Since a portion of this is considered agronomic to break down the rice stubble, the additional environmental water is estimated at 3-inches per acre. 5,000 acre federal refuges at 4.5 AF/ac; Required to maintain 6 cfs flows down drain from June 1 through October 30 for habitat (approx. 12 AF/day).	Canal habitat = 6,000 AF per year Field = 15,000 AF per year Refuge = 22,500 AF per year Drain flows = 1,800 AF per year
Recoverable Flows	This value is estimated using several different sources of data and calculations. First, data is obtained from gauges on major drains, which represented approx. 90% of the surface return flows. Second, using information on delivered water quality and estimates of the portion of agronomic water used to leach salts, an estimate of deep percolation associated with beneficial agronomic uses is derived. Third, using the results of the $RBUF_T$ equation, the remaining portion of the total delivered water that is not crop ET, agronomic water or intended environmental water is identified. Of this, an estimate is made as to how much of this water evaporates or is used by non-crop plants that are not part of intentional environmental	Drain data = 14,560 AF per year Estimated deep percolation from leaching = 33,330 AF per year (2 inches per acre) Estimated additional deep percolation (not from leaching) = Step 1 = 986,990-924,800 = 62,190 AF Step 2 = assume 20% of this evaporates from delivery system and/or is ET of incidental plants within regional boundary. Step 3 = 80% (62,190)

TABLE 3-3

Regional Scale Example of Primary and Secondary Agricultural Water Use Methods (see also table 3-1 for additional applicable details)

Quantifying the Efficiency of Agricultural Water Use

Data Element	Calculation	Result
	objectives. The portion remaining is considered returning as additional deep percolation to that from intentional leaching.	= 49,752 AF per year Total estimated recoverable flows = 14,560 + 33,330 + 49,752 = 97,642 AF per year
Aggregate Field Scale Applied Water	Estimate provided by water supplier in monthly measured billings and reported per CWC §531.10. Field level groundwater pumping and net change in surface storage and/or soil moisture accounted for.	Aggregate Applied Water = 943,485 AF per year
Regional Scale Applied Water	The total quantity diverted by the suppliers and water right holders in the region is derived from records maintained for filing to the SWRCB. The quantity of privately pumped groundwater is estimated from the change in groundwater elevation between spring and fall readings in several monitoring wells within the regional boundary combined with hydro-geological data from prior studies relating elevation change to volumes. Total deliveries to non-irrigation agriculture and M&I are subtracted from the total. Delivered water also excludes groundwater recharge and accounts for the net change in surface storage.	Supplier diversions = 676,890 AF per year Private diversion = 245,600 AF per year Refuge diversions = 30,000 AF per year Estimated GW pumped = 134,500 AF per year Supplier non-irrigation agricultural deliveries = 80,000 AF per year Supplier M&I deliveries = 20,000 AF per year No groundwater recharge or net change in surface storage. Applied water per year= 986,990 AF per year
Equations:		
CUF	= 795,000/986,990	= 81%
BUF_A	= (795,000+62,000)/986,990	=87%
BUF_T	= 902,300/986,990	= 91%
DF	= (943,485)/986,990	= 96%
WMF	= (795,000 + 97,642) /986,990	= 90%

Productivity Methodology for Quantifying the Efficiency of Agricultural Water Use

Productivity indicators and associated procedures to quantify the efficiency of agricultural water use have been developed. The set of indicators and procedures are intended to evaluate the efficiency of agricultural water use for different purposes at different scales. These indicators are:

- Productivity indicators applicable to the field, county and statewide scales:
  - Productivity of Applied Water Fraction
  - Value of Applied Water Fraction

This section describes each indicator in detail. The appropriate elements used to calculate the indicator are identified and the purpose and examples of each indicator are provided at each applicable geographic scale.

4.1 Productivity Approach

As specified in Section 2.3.3, a possible alternative method to the traditional hydraulic measure of efficiency is to evaluate indicators that demonstrate the relation between crop productivity or gross crop revenue and associated crop water use. Components of a water balance (Section 3.1) along with measures of productivity are used in the methodology for quantifying productivity indicators related to the efficiency of agricultural water use. These measures of productivity are:

1. *Gross revenue of crop production =* Gross revenue received by the grower is the weight of production multiplied by the price per unit weight of crop.
2. *Weight of crop production =* Total production of each crop during a given timeframe, usually one or more production seasons, measured in tons or hundredweight.

Although productivity indicators are related to economic efficiency and can be used to help guide public policy and public investment, an understanding of their limitations is essential so they are not misused. Economic efficiency conditions rely on marginal responses and rates of trade-off. Generally, these are not directly observable using aggregate data or even producer-scale or field-scale data. Any approach to quantifying the economic efficiency of agricultural water use may assign too much of any apparent inefficiency to water use. Individual constraints on crop production (such as shortages of other factors of production), variation in land quality, improperly specified production functions, or incomplete understanding of risk and uncertainty can appear to analysts to be inefficiency. If water use is the focus of the analysis, there can be a tendency to blame it for inefficiency in crop production rather than other factors.

Crop productivity indicators should not be used to draw firm conclusions about which crops or regions are using water in more or less economically efficient ways. However, indicators can be developed to show broad comparisons between regions or crops or over time for a given region or crop.

4.2 Indicators

The following agricultural water use efficiency indicators are applicable at the field, county, and statewide scales:

- Indicator 1: Productivity of Applied Water Fraction (PAW) – This indicator illustrates the relationship between irrigated agricultural production and the quantity of applied water in a field or county boundary or statewide to meet the consumptive needs of irrigated agriculture. The numerator of the equation would include the total crop production by weight or other recognized measure of yield, and the denominator would be the total applied water to the field, at the county or statewide. This indicator must be calculated separately for each crop to avoid adding together disparate physical units of different crops. As a result, the total applied water also needs to be estimated separately by crop. Few irrigated areas in California maintain any standard record of groundwater use on a crop-specific basis. Some, but not all, suppliers maintain records of crop-specific deliveries to fields. Therefore, in most cases, estimates would have to rely on growers' field records. Suppliers' delivery records could be used if they could be matched to a particular crop and if the supplier or analyst were confident that no private pumping or other diversions were used to irrigate the crop. The field indicator relies on the crop production from the field and the applied water to the field. Both these values are only available to growers, therefore, the field scale indicator is only suggested for growers' use.

- Indicator 2: Value of Applied Water Fraction (VAW) – This indicator illustrates the relationship between the gross crop value of irrigated agricultural and the quantity of applied water in a field or county boundary to meet the consumptive needs of irrigated agriculture. The numerator of the equation would include the total gross crop value of irrigated agricultural (price multiplied by yield), where the denominator would be the total applied water used to meet the needs of irrigated agriculture. The total gross crop value of irrigated agriculture for a county is used in this indicator given the difficulty of estimating applied water by county directed towards a specific crop type. The denominator would be the delivered water and groundwater pumping for irrigated agriculture within a county. Crop-specific estimates could also be made based on individual grower records, as described for the PAW indicator. The field indicator relies on the crop value from the field and the applied water to the field. Both these values may only be available to growers, therefore, the field scale indicator is only suggested for growers' use.

Estimating crop-specific productivity and economic value is a technical challenge because information needed to attribute groundwater use, and in some cases surface water delivery, to any individual crop types is sparse. Both total value of production and total applied water (including measured or estimated groundwater use) can be estimated within a defined boundary, so VAW can be calculated at a county level using aggregate data. Some gross estimates of applied water by individual crop can be obtained from University of California Cooperative Extension crop production budgets. However, these are characterized as example budgets with example, or typical, water use estimates – they are not claimed to be based on careful, statistically valid measurements. These estimates can be used initially to provide a very general comparison. However, field-level data from individual grower records is the only reliable source, in most cases, of accurate and comprehensive water use for crop-specific estimates. These field-level data can then be aggregated to generate estimates at larger scales such as counties.

These crop productivity indicators are not strictly measuring the efficiency of agricultural water use. Other factors such as water quality, soil salinity, soil nutrients, and other soil conditions, differences in varieties, insect pressure, crop rotation, weather, crop markets, fertilizer and other production inputs, and management for crop quality rather than yield are often more important in explaining differences in the value of the indicator than is water management.

The productivity and economic value indicators may be better estimated at the field scale. At this scale, these indicators may be more practically useful as they provide the grower with a tool to evaluate the profitability of their business operations.

4.3 Examples of Calculating Indicators

Understanding the potential purposes at each scale provides insight into the development and use of the indicators in this methodology. To help understand the applicability of the indicators, the following provides suggested purposes, coupled with a detailed example of calculating the various indicators. None of the assumptions made in these examples may be appropriate for application.

Drawing directly from policy statements and other language in the enabling legislation, several purposes have been suggested to evaluate the relationships of crop productivity or value of production (gross crop revenue) to agricultural water use. The purposes include:

1. Evaluate crop production (in weight or gross crop revenue) per acre-foot of applied water within a defined scale.
2. Evaluate how production (in weight or gross crop revenue) per acre-feet changed over time within a defined scale.

4.3.1 **A County Scale Example**

A productivity approach might include all acres of irrigated agriculture within a county. Using this example, the productivity indicators are calculated in Table 4-1.

TABLE 4-1
Productivity Example of Agricultural Water Use Efficiency Indicators at the county scale (for field scale, the production, applied water and crop value are collected by the grower).
Quantifying the Efficiency of Agricultural Water Use

Data Element	Calculation	Result
Weight of crop production	Example Method 1 – use County Ag Commissioner reports and USDA NASS data, area-weighted for overlying counties Example Method 2 – survey of growers, local processers	Method 1 = 44.5 tons/acre x 73,000 acres = 3.25 million tons Method 2 = 46.2 tons/acre x 78,200 acres = 3.61 million tons
Gross revenue of crop production	Example Method 1 – Use Ag Commissioner reports and USDA NASS data, area-weighted for overlying counties Example Method 2 – survey of growers, local processers	Method 1 = \$56.70 \$/ton x 44.5 tons/acre x 73,000 acres = \$184.2 million Method 2 = \$58.20 \$/ton x 46.2 tons/acre x 78,200 acres = \$210.3 million
County Applied Water	Supplier delivery provided by DWR from the Water Plan Update water balance studies	Method 1 = 135,050 AF
Equations:		
PAW	Calculate range for both methods of estimating production	Low: 3.25 MT/135,050 AF = 24 tons/AF High: 3.61 MT/135,050 AF = 26.75 tons/AF
VAW	Calculate range for both methods of estimating gross revenue of production	Low: \$184.2 million/135,050 AF = \$1,362/AF High: \$210.3/135,050 AF = \$1,557/AF

[Placeholder – entire application text is anticipated sidebar discussion]

Water Supplier Level – Example Application of Methods

Scenario: A water supplier in the Sacramento Valley has recently installed distribution system improvements to help reduce spill out of the end of the distribution system as one of its efforts to implement locally cost-effective efficient water management practices [see CWC §10608.48(c)(7)]. As required reporting in its subsequent Agricultural Water Management Plan, the supplier intends to use these improvements to help document an "estimate of the water use efficiency improvements that have occurred since the last report" [CWC§10608.48(d)].

Chosen method: Because the implemented measure directly impacts delivery system operations, the supplier has chosen to calculate the Water Supplier Delivery Fraction to demonstrate the "efficiency improvements" that have occurred.

Data required:

Aggregated Farm gate Deliveries: Reported §531.10 values for delivery year prior to an following system improvement (may be an average of several years prior and several years after, depending on timing of the AWMP and variations in cropping or other factors that might bias the before/after comparison). It is assumed that the supplier does not have water reuse system during the evaluation period.

Water Supplier Total Diverted (net): For each of the years corresponding to the aggregated farm gate delivery values, the quantity of diversions reported to the SWRCB

SIDEBAR TABLE 1
Total Diverted Water
Quantifying the Efficiency of Agricultural Water Use

Year	Aggregated Farm gate Delivery	Water Supplier Total Diverted (net)	Supplier Delivery Fraction
2008	45,670	56,745	80%
2008	48,038	59,986	80%
2009	43,946	55,012	80%
Average	45,884	57,248	80%
2010	46,732	56,349	83%

Results:

Supplier Distribution Fraction = Aggregated Farm Gate Deliveries/Total Diverted (net)

1. Prior to installation SDF = 80% (average of prior 3 years)
2. Post installationSDF = 83%

The Supplier Distribution Fraction is estimated to have increased 3 percentage points as a result of the implemented EWMP. The Supplier would report this information in its upcoming AWMP.

Regional Level – Example Application of Methods
Scenario: The 2013 California Water Plan development is underway, anticipating a draft to be published in April of 2013. The Department wants to publish "current condition" information to illustrate the efficiency of regional agricultural water use. The information would be determined using the existing Detailed Analysis Unit (DAU) regional boundaries, but reported at the hydrologic region level in each of the "Regional Reports" (expected to be completed in August 2013).

Chosen method: To provide a broad understanding of current agricultural water use at the regional level, the Department will calculate the RCUF, $RBUF_A$, and $RBUF_T$. The combination of these three primary methods to understand current regional water management conditions will help establish the foundation for future determinations at the regional scale in subsequent California Water Plan updates.

***Data required**:*

ETAW: The Department's regional staff currently develops water balances at the DAU-County level, including determinations of ETAW. This information will be used to populate the regional ETAW values.

Agronomic Water (net): Using water balances generated at the DAU scale, Department regional staff will estimate the crop agronomic needs as currently reflected in various agronomic practices around the state. For instance, based on local knowledge, the staff in the South Central Region office understands the current leaching practices that vary with water source, crop, and soil conditions throughout the southern San Joaquin Valley. This knowledge is translated to estimate net agronomic needs for purposes such as leaching. Consistently using an approach to determining agronomic needs will allow comparable values as determined in future Water Plan updates.

Environmental Water: Similar to the agronomic water data determinations, water directed toward intended environmental purposes will be derived by the Department's regional staff using information from the DAU water balances.

Regional Total Diverted Water (net): This value is already developed as part of the Department's regional water balance efforts.

Results: This representation (example data only) of regional agricultural water use relationships provides a basis for comparative trends in future California Water Plan updates.

SIDEBAR TABLE 2
Regional Scale Agricultural Water Efficiency
Quantifying the Efficiency of Agricultural Water Use

"Current" Regional Agricultural Water Use Efficiency Values (not based on actual data)

Region	CUF	BUF_A	BUF_T
North Coast	75%	77%	77%
San Francisco Bay			
Central Coast			
South Coast			
Sacramento River	79%	82%	86%
San Joaquin River	77%	81%	84%
Tulare Lake	85%	88%	88%
North Lahontan			
South Lahontan			
Colorado River	78%	87%	89%

SAMPLE DATA

Field Level – Example Application of Methods

Scenario: A local environmental coalition is confident improvements in on-farm irrigation management can reduce diversions on a small stream so that water can be left instream to benefit identified ecosystem objectives without affecting existing farming. The local coalition is interested in demonstrating to the local water users that these improvements can be funded through water conservation grants, but need to demonstrate the "improvements in efficiency" that would result from the projects, as required in the grant application. The local users have voluntarily agreed to help the coalition pursue grant funds to implement on-farm irrigation system improvements.

Chosen method: The coalition will document the existing CUF of four different fields served by four unique stream diversions. An estimated reduction in applied water from modified irrigation management will be shown to reduce one of the factors – applied water – and show an improvement in CUF.

Data required:

ETAW: Using data from a local CIMIS station, coupled with detailed farmer-provided crop information, and precipitation data the coalition is able to calculate the ETAW for the existing crops served by the existing four stream diversions.

Applied Water: Each farmer has associated diversion records for their respective diversions that are provided to the coalition to support the grant application. The diversions are also all appropriative water rights under the authority of the State Water Resource Control Board with reporting of permittee or licensee as applicable to each diverter.

Results:

As shown in the table, the coalition's anticipated on-farm irrigation improvements will have noticeable improvements in the CUF. This information will be provided, along with detailed descriptions of the planned improvements, in the coalition's grant application.

SIDEBAR TABLE 3
Field Scale Agricultural Water Efficiency
Quantifying the Efficiency of Agricultural Water Use

	Existing ETAW	Existing AW	Existing CUF	Anticipated AW	New CUF
Field 1	654	865	76%	810	81%
Field 2	432	687	63%	550	79%
Field 3	1475	2150	69%	1950	76%
Field 4	846	1291	66%	1100	77%

Plan for Implementation

5.1 Implementation Requirements

Key elements of the plan for implementation include:

- The methods and indicators to be implements and the appropriate geographic scales
- The entities that should implement the methodology, and coordination with existing data and reporting activities. A description of data needed to support the methodology, the data sources, and the quality and limitations of data
- The schedule and frequency of applying the methodology, including appropriate phasing
- The estimated cost of acquiring data and implementing methods.

5.2 Implementation Plan

The legislation did not authorize implementation of a methodology and did not identify any source of funding for any possible future implementation. DWR proposes that if the methodology is authorized for implementation, necessary sources of funding should be identified to support the implementation at all scales. In the implementation cost section, DWR estimates the approximate level of funding for implementation at all four scales.

Although Section 10608.64 of the California Water Code does not specify the implementing agency, DWR proposes that it assume the following three responsibilities, if and when the implementation is authorized and the necessary resources are provided. DWR assumes this role because it can provide consistency in implementation and can help in maintaining and disseminating the information from quantification of efficiency of agricultural water use reported to it by the agricultural water suppliers or others.

(1) DWR will develop data standards, data collection protocols, schedules, quality control, and quality assurance and provide assistance to agricultural water suppliers, growers, and other cooperating agencies in implementation of the report recommendations.

(2) DWR also will implement the productivity indicators at the county and statewide scales. DWR's Water Plan Update process can provide the means for data collection and analysis needed to quantify statewide and county scale productivity indicators.

(3) DWR will implement the water management regional scale methods. The Water Plan Update process can provide the means for data collection and analysis needed to quantify the regional methods.

(4) DWR in cooperation with interested entities to develop an agreement for implementation of the field scale methods.

(5) DWR will include aggregated results of field scale in the WPU.

Depending on the affected geographic scale, the implementation of the established methodology could be carried out by using existing programs to the extent possible, and by expanding them, creating new programs, or reviving abandoned programs where needed. The existing programs may include agricultural water suppliers' preparation of agricultural water management plans required by section 10820 of the CWC, implementation of efficient water management practices required by section 10608.48, and agricultural water suppliers' reports of estimated efficiency improvements as required by 10608.48 (d). Other existing programs include aggregate water delivery reported under section 531.10 of the CWC and preparation of the California Water Plan Update. Implementation also includes collaboration with the Agricultural Water Management Council, agricultural water suppliers, academic and research institutions and California universities, and other cooperating agencies.

For supplier scale methods, the agricultural suppliers can use information collected for and provided in agricultural water management plans, plus other available agricultural water use data (e.g., aggregate farm-gate deliveries submitted to DWR pursuant to CWC 531.10). Some of the data elements needed to calculate water management methods 1 through 5 are reported under the agricultural water management plans. Crop-specific water use and methods can be estimated by some suppliers using their own delivery records, and others may be able to use aggregated field-level data as it becomes available. Collaboration between DWR and agricultural water suppliers may be necessary for calculation of certain supplier scale methods.

For field scale methods, the field scale data would be collected through a voluntary program. The program objectives are twofold: 1) provide the farmers with useful data and an assessment of their water use efficiency in order to improve their operations; and 2) provide State and local water management and planning entities with aggregate field scale water use data. The program will be in the form of technical assistance offered to willing participants from the farming community. Collected data will be aggregated and all information identifying specific fields, growers or landowners will be removed to protect privacy.DWR will work with cooperating agencies, including the Agricultural Water Management Council, agricultural water suppliers, Resource Conservation Districts, University of California Cooperative Extension, and other research institutions such as Cal Poly or the Center for Irrigation Technology at California State University, Fresno. These field evaluations will be offered to voluntary participating growers, and will be similar to the mobile lab program that DWR has supported through cost-sharing arrangements. The mobile labs combined with additional field level data constitute the best approach for acquiring reliable field level water use data.

Field scale productivity indicators are only proposed for use by growers at the field scale and are not included in the plan of implementation.

5.2.1 Field Scale

5.2.1.1 Data Collection

The field scale methods use data collected from individual fields or estimated to represent categories of individual fields. Categories can be defined by region, crop type, irrigation system, soil type, and other factors.

Growers often measure and use information on applied water, crop water use, soil moisture, distribution uniformity, and return flow. They use these data to manage irrigation and production and to understand and control costs. They generally do not provide this information to others. There is a wide variation in the techniques used to measure or estimate field-level water use. They may use different techniques to measure or estimate field water use. If they use the estimates to calculate fractions indicating their efficiency of water use, those fractions may or may not be consistent with the ones defined in this report. The methods proposed here will provide a consistent approach for quantifying the efficiency of water use.

DWR considered several approaches for gathering field level data for the purposes of quantifying the efficiency of agricultural water use at the field scale. Its recommended approach is a co-operative cost share program to gather field-level water use data. A field evaluation service would be provided on a voluntary basis to growers selected to provide a representative sample of fields by region, crop, irrigation system, and other appropriate factors. The data collected would be provided to the growers for making improvements in their water management practices. Collected data stripped from any personal or business information will also be used by participating local and State agencies for improving local, regional, and statewide water management and planning. DWR has in the past funded mobile labs in a cost share arrangement with water suppliers. This can be a phased approach starting with supporting the existing mobile labs and potentially expanding to additional mobile labs to provide a larger and more representative sample of fields.

5.2.1.2 Data Sources, Quality, and Limitations

The availability and quality of field level water use data varies significantly. Some data are measured with a high degree of accuracy by some growers but lower accuracy by others. Some growers may calculate crop ET, and some may keep track of water applied for specific, non-consumptive agronomic uses. Environmental uses of water that are incidental to crop irrigation activities would generally not be monitored or estimated by growers, whereas water applied specifically for environmental uses (such as winter field flooding for waterfowl) might be recorded.

Field-level water applications include water delivered to the field by the water supplier, groundwater pumped from private wells, and water reused from other fields (if it has not been delivered through the supplier's system). Many water suppliers maintain records of their water deliveries by field, but may not record the crop grown or the planting and harvest dates. Other water suppliers measure and record deliveries to turnouts but not necessarily to individual fields. Growers view individual field records as proprietary business information, and suppliers do not release information by field, though some could provide aggregated data by crop for instance. For most irrigated lands in California, private groundwater use by field is recorded only by the growers themselves. On-farm reuse of water would be recorded if done by the grower. As a result, quantification of field-level water use efficiency must rely on grower-supplied data, data gathered during field-level studies, or new data gathered from field-level measurements such as through mobile lab evaluations.

Collection of data at the field scale requires measurement of applied water, estimation of ETAW for an irrigation event or for a season therefore requiring calculation of the duration of this period, collection of crop coefficient data for the crop(s), calculation of leaching requirement and knowledge of water quality and crop salinity tolerance, and measurement of water needed for frost control and other agronomic needs and estimation of effective precipitation. These data are often not available to the growers and collection of data requires expenditure of funds. The availability of these data and quality of the data collected determine the accuracy of the calculated water management indicators.

While most farmers have good delivery records of their water deliveries it is uncertain if they have the applied water to each field and most farmers do not measure groundwater pumping delivered to the field and if it is measured the data is not publicly available. Also some farmers may have their crop consumptive use. The ETAW is normally calculated using CIMIS data from previous periods (season) and therefore if applied to future it is an estimate of future conditions. Also, CIMIS stations may not represent the field location unless local weather station is used for calculation of consumptive use. Effective precipitation, agronomic water needs are mostly unavailable to the farmers, therefore have to be quantified during filed evaluation by the mobile lab.

Table 5-1 provides a summary of likely sources of data for field methods, and identifies options and needed improvements.

Calculations of the Agronomic and Total Beneficial Use Fractions will necessarily be limited and qualified in early implementation years. The next section includes recommendations for improved data collection and estimation of some water flows in order to support the methodology.

TABLE 5-1
Field Scale Data Sources and Options (see also table 3-1 for additional applicable details).
Quantifying the Efficiency of Agricultural Water Use

Data Component	Source or Options	Notes
Distribution Uniformity	quantified by mobile labs during field evaluation	
Crop ET and ETAW	Method 1: use available CIMIS station data and typical Kc for crop Method 2: use results from field evaluation to calculate field-specific Kc and/or reference ET Method 3: use processed satellite imagery to calculate for specific field	Other optional methods are possible. More than one source available for processed satellite imagery.
Applied Water	Results from field evaluation, it may have to be measured during field evaluation. Grower or supplier records.	Suppliers' individual field delivery records are generally private. GW use on individual fields is not reported.
Agronomic Needs	Results from field evaluation, grower records Standard or typical agronomic uses could be calculated for local conditions. For example, leaching requirement can be based on applied water quality, crop, soil and drainage conditions. References to be added for sources of information or calculation (add reference or equation)	A standard estimation procedure could be developed during data assessment phase.

TABLE 5-1
Field Scale Data Sources and Options (see also table 3-1 for additional applicable details).
Quantifying the Efficiency of Agricultural Water Use

Data Component	Source or Options	Notes
Environmental Needs	Information could be collected during field evaluation. Typical environmental uses could be calculated for local conditions, though limited studies and estimates available. Include environmental needs required and quantified for regulatory or permit processes.	DWR work with suppliers, DFG and USFWS, and other groups to develop estimation procedure during data assessment phase.

5.2.1.3 Data Collection Responsibility

DWR recommends a cost share program to gather field-level water use data for quantification of CUF, DU, IF, BUF, TBUF. DWR would support the program in cooperation with interested entities such as the Agricultural Water Management Council, water suppliers, US Bureau of Reclamation, USDA Natural Resources Conservation Service, Resource Conservation Districts, university cooperative extensions, or other entities to provide an irrigation and water use evaluation service, modeled on the Mobile Labs, to cooperating growers. The service would be provided to growers selected to provide a representative sample of fields by region, crop, irrigation system, and other appropriate factors. The data collected during field evaluation would be provided to the grower to manage and improve irrigation operations. Field owners and operators may also collect data such as water deliveries to the field, ET, or agronomic and environmental needs to be used for the field scale methods. Field evaluation data will be aggregated by the mobile lab evaluation service entity and submitted to the water supplier or the government agencies sponsoring the mobile lab evaluations for planning and educational purposes. Protocols for confidentiality will be developed to ensure that information identifying individual fields, owners, or operators will be removed.

5.2.1.4 Schedule of Implementation

Data availability, quality, and consistency is a clearly identified need for useful implementation for all of the geographic scales, but it is especially so at the field scale. DWR recommends that implementation of the field methodology occur in several phases. An initial assessment is needed that collects and assesses the existing data, and develops priorities for the collection of improved field data. Representative samples of fields would be developed based on the priorities, available resources, and willing grower participants. The second phase would focus on collecting new field estimates of water uses and flows, using detailed field evaluations that include Mobile Lab estimates of irrigation system performance and distribution uniformity. Resources would be allocated according to the priorities developed in Phase 1. This second, data improvement phase can be scaled to match resources available by adjusting the sample size of fields evaluated and by narrowing or broadening the number of priorities addressed simultaneously (the effect would be to lengthen the number of years over which the data would be improved during this phase). Quantification methods could be applied and updated on a regular basis during this phase. DWR would refine the methods and data standards and protocols as needed.

Phase 1: Complete by 2015

- Cooperating agencies and entities develop an agreement defining the roles and responsibilities and resources needed for implementation.
- Identify a small number of cooperating agencies with existing field-level data from Mobile Labs and water supplier delivery records. Cooperators use this data to make initial calculations of methods.
- DWR and cooperators identify important data needs and priorities for improvements. Priorities could be based on data components (e.g., field-level ET estimates versus water applied versus agronomic uses), crop categories, regions, irrigation methods, or other factors. Priorities could also be based on statewide or regional water management considerations.

- Develop a plan to improve the key limiting data in Phase 2. Based on expected budget or on a range of potential budgets, develop a sampling plan to identify representative numbers of fields according to the priorities.
- Identify existing mobile lab resources and develop a funding plan to expand as needed to match priorities and budget.

Phase 2: Complete by 2020

- Based on priorities and available funding, DWR and cooperating agencies implement the data improvement recommendations from Phase 1.
- Select a region and/or crop as a pilot test to apply the methods using the improved data. Assess results and revise data improvement recommendations if necessary.
- Calculate methods and update regularly as improved data is collected and data standards are updated.
- DWR will provide a status report to the legislature in 2021 with the summary of findings.

Phase 3: Begin after 2020

- Apply improved data collection and estimation processes and implement methods for all regions and crops. An ongoing field sampling program would be part of this phase. Methods would be calculated on a regular basis.

Table 5-2 provides a summary of the implementation plan for the field scale.

TABLE 5-2
Summary of Implementation Plan Elements for Field Scale Methods
Quantifying the Efficiency of Agricultural Water Use

Implementation Plan Element	Details	Notes
Methods	Distribution Uniformity, Crop Consumptive Use Fraction, Agronomic Beneficial Use Fraction, Total Beneficial Use Fraction	Methods calculated by crop type and irrigation system. Results aggregated by region, supplier, or other scale
Implementing Entities	Cooperating growers or Water suppliers, and other willing agency cooperators (DWR, USBR, USDA NRCS, UC Cooperative Extension, RCD) .	Coordinate aggregate data reporting process with suppliers and other cooperators within region
Data Sources	See Table 5-1	Privacy of data from individual fields protected
Schedule and frequency	Initial phase: by 2015 calculate using best existing data and estimates. Develop program to improve and expand database of field-level water use information. Second phase: by 2020, fund and implement data improvement plan. Implement mobile lab (or similar) program. Ongoing: : if available agricultural water suppliers should include the aggregated field scale results as part of agricultural water management plan. Aggregated regional results reported in CWP update every 5 years.	Data improvement plan could provide options to the legislature, with associated cost and other implications. Options could include: focus on high priority regions or crops; broad implementation at moderate pace; or broad implementation at more rapid pace.
Cost	See Cost Estimate section	

5.2.2 **Water Supplier Scale**

5.2.2.1 Data Collection

Agricultural water suppliers vary greatly in size, and supplier scale methods use data that may cover up to hundreds of thousands of acres. Agricultural water suppliers subject to the water management planning provisions of SBx7-7 (greater than 25,000 irrigated acres, and between 10,000 and 25,000 irrigated acres if sufficient funding is provided) would already be providing much of this information in their Agricultural Water Management Plans (AWMPs).

Data collection at the water supplier scale is the responsibility of the agricultural water supplier. Agricultural water suppliers report data required by section 10826 (a) and 10826 (e) in their AWMPs. Data needed for calculating the methods are ETAW, agronomic and environmental needs, supplier's recycled water, recoverable flows (flow outside the boundary of supplier), and any storage or depletion from the supplier reservoirs. DWR will use the data from the AWMPs in calculating the various water management regional methods.

Suppliers would provide data they already gather and report in AWMPs every five years. This could include data a supplier provides on diversions, deliveries to irrigated fields, operational spill, seepage, supplier-level reuse, and any estimates it has made of water uses within its boundaries, including ETAW, private groundwater pumping, agronomic needs, and environmental uses.

Supplier scale data rely on estimates and measurements reported by suppliers in AWMPs and AB1404 reports in combination with estimates developed by DWR regional analysts. For water use estimates not provided by suppliers, GIS and other analytical tools would be used to parse DWR's regional scale estimates into supplier scale estimates. The formal coordination of the regional and supplier estimates will serve as a cross check on different data sources and result in improved understanding of water uses at both scales. Cooperation between DWR and water suppliers may be necessary for additional information as needed to calculate the supplier-level methods to quantify efficiency of agricultural water use, and report these results in the AWMPs.

5.2.2.2 Data Sources, Quality, and Limitations

The quality of existing data needed to implement the methodology varies significantly across suppliers and data categories. This presents the largest challenge to generating useful information from the methodology. Some data are measured with a high degree of accuracy, some at a lower accuracy, and some important data are not measured at all and must be estimated. Estimation methods can be independent of the regional water balance activity, or it can use the balancing of water supplies with water uses to derive (back-calculate) a component of the water balance. Table 5-3 provides a summary of likely sources of data for supplier methods, and identifies options and needed improvements.

Groundwater pumping is a particularly important part of overall agricultural water use that is not measured directly for the majority of irrigated areas in California. Other components such as reuse, return flow, seepage losses, and operational spill are generally estimated, but with varying degrees of accuracy. Even crop evapotranspiration estimates used for supplier water budgets reported in AWMPs may rely on generalized coefficients in the absence of good, localized estimates.

Agronomic uses are already estimated by some suppliers, but the current estimation procedure is likely not standardized. Just as some of the water applied to refill the root zone runs off or percolates, some of the water applied for, say frost control, exceeds the minimum "needed" to accomplish the task. Environmental uses are not generally estimated except as part of a targeted study or regulatory requirements. Calculations of the Agronomic and Total Beneficial Use Fractions will necessarily be limited and qualified in early implementation years. The next section includes recommendations for improved data collection and estimation of some water flows in order to support the overall methodology.

Water suppliers have reasonably good record of their water deliveries. Cropping information is often provided to the water supplier voluntarily and the quality of the data is uncertain, therefore water suppliers may have to utilize their staff to estimate the crop area and crop consumptive us. Effective precipitation can be calculated from the records but it is an estimated value and estimation methodology may need to be updated. The agronomic needs have to be estimated.

TABLE 5-3
Supplier Scale Data Sources and Options
Quantifying the Efficiency of Agricultural Water Use

Data Component	Source or Options	Notes
Crop ET and ETAW	Supplier-level ET: Method 1: supplier-level ETo and Kc Method 2: aggregate the more detailed field-level data Method 3: processed satellite imagery	Aggregated field data gathered from field evaluations (see field-level implementation). More than one source available for processed satellite imagery.
Applied Water	Method 1: surface water from suppliers; Private water rights diversions from SWRCB; groundwater estimated Method 2: aggregate the more detailed field-level data	Use aggregate reporting of delivery as it becomes available GW use is unmeasured. Aggregated field data gathered from field evaluations
Agronomic Needs	Options: aggregated from field-level evaluations; reported by suppliers; estimated by DWR	Is a standard estimation procedure needed? Need to address in data assessment phase.
Environmental Needs	Information could be collected during field evaluation. "Typical" for the local conditions, though limited studies and estimates available or from regulatory requirements.	DWR work with suppliers, DFG and USFWS, and other groups to develop estimation procedure.
Aggregated farm-gate delivery and total diverted water	Reported by suppliers	Use aggregate reporting of delivery as it becomes available; data reported in AWMPs; SWRCB diversion reports.

5.2.2.3 Data Collection Responsibility

Data collection at the water supplier scale is the responsibility of the agricultural water suppliers.

5.2.2.4 Schedule of Implementation

The methods will be calculated and included in AWMPs (CWC 10826) using data collected and reported in the AWMPs and in the aggregated farm-gate delivery annual report to DWR required per CWC 531.10. Implementation of the supplier methodology should occur in several phases, extending over a period of five years. Phasing will allow the use of existing data to prepare initial estimates of the supplier level methods while data improvements are identified and implemented.

Phase 1: Complete by 2015

- Agricultural water suppliers with existing data make initial calculations of methods. Cooperating suppliers would preferably have relatively good existing data on delivery records, reuse, seepage, and operational spill, plus some existing estimates of private groundwater pumping, agronomic uses, and environmental uses. Water suppliers report the information in AWMP.

- DWR and cooperators identify important data needs and priorities for improvements. Priorities could be based on data components (e.g., agronomic uses and environmental uses), crop categories, regions, or other factors. Priorities could also be based on statewide or regional water management considerations.
- Develop a plan to improve the key limiting data in Phase 2, based on expected costs or on a range of potential costs and available funds

Phase 2: Complete by 2020

- As a small-scale pilot test, select a small number of suppliers to implement the data improvement recommendations and apply the methods using the improved data. These suppliers would report results in their 2020 AWMPs.
- DWR, cooperating suppliers, and other experts assess results and revise data improvement recommendations if necessary.
- Other suppliers provide methods in 2020 AWMPs, using the best existing available data.

Phase 3: Begin after 2020

- All suppliers preparing AWMPs implement data improvement plan, calculate supplier-level methods and report them in their AWMPs

TABLE 5-4
Summary of Implementation Plan Elements for Supplier Scale Methods
Quantifying the Efficiency of Agricultural Water Use

Implementation Plan Element	Details	Notes
Methods	Supplier CUF, Supplier Agronomic Beneficial Use Fraction, Supplier Total Beneficial Use Fraction Supplier Delivery Fraction	
Implementing Entities	Supplier that prepare AWMPs. DWR regional land and water use analysis units and/or statewide unit could provide data and technical assistance.	Coordination process to be developed.
Data Sources	See Table 5-3	
Schedule and frequency	Initial phase: by 2015 cooperating suppliers calculate using best existing data and estimates. Develop program to improve supplier-level water use information. Second phase: by 2020, fund and implement data improvement plan as pilot test. All suppliers use best existing data to calculate methods and report in 2020 AWMP Ongoing: if available suppliers should include the aggregated field scale results as part of AWMP every 5 years.	Data improvement plan to focus on groundwater, agronomic uses, and environmental uses. Plan could provide options to the legislature, with associated cost and other implications. Pilot testing to focus on high priority regions or crops; incorporate aggregated field-level data as it becomes available.
Cost	See cost estimate section	

5.2.3 DWR Hydrologic Region Scale

5.2.3.1 Data Collection

The regional scale methods use data that may cover hundreds of thousands of acres and may span multiple water suppliers. DWR considered two existing regional entities and processes that provide data gathering, analysis, reporting, and management. These processes are summarized below:

- Regions accepted under the DWR's Integrated Regional Water Management (IRWM) program. These regions represent groups of local water suppliers and other agencies that prepare regional plans and are eligible for state funding to implement elements of those plans. IRWM regions are a developing concept and some regions have not begun coordinated planning activities. Substantial variation exists among regions in their planning budgets and capabilities. DWR eliminated them from consideration for regional scale implementation. Counties were also considered, but they vary widely in their water management activities and capabilities, and they do not generally correspond well to water shed or other water management boundaries.
- DWR land and water use analysis is conducted in support of the California Water Plan Update. This is an extensive, ongoing activity that gathers water use and supply data at various regional scales, develops estimates of water use or supply quantities that are not directly measured, and uses the information to construct water balances. Water use and supply estimates are made at the level of detailed analysis units (DAUs) as defined in the California WPU and at subareas of DAUs delineated by county lines. These estimates are aggregated into 10 larger areas called hydrologic regions (HRs), corresponding to the state's major water drainage basins. DWR proposes that its land and water use analysts be responsible for implementing the quantification methods and reporting them for hydrologic regions as part of the periodic WPU.

5.2.3.2 Data Sources, Quality, and Limitations

The quality of existing data needed to implement the methodology varies significantly across regions and data categories. This presents the largest challenge to generating useful information from the regional methods. Some data are measured with a high degree of accuracy, some at a lower accuracy, and some important data are not measured at all and must be estimated. Estimation of key data can be independent of the regional water balance activity, or the balancing of water supplies with water uses can be used to derive (back-calculate) a component of the water balance.

DWR land and water use analysts already develop data to provide initial estimates of regional consumptive use fractions, water management fractions, and delivery fractions. The major limitations are regional groundwater pumping estimates, components of agronomic use, and environmental uses by growers.

Groundwater pumping is a particularly important part of overall agricultural water use that is not measured directly for the majority of irrigated areas in California. Other components such as reuse, return flow, and seepage are generally estimated with varying degrees of accuracy. Even crop evapotranspiration estimates used for regional water balances may rely on generalized coefficients in the absence of good, localized estimates that are aggregated to a regional scale.

Table 5-5 provides a summary of likely sources of data for regional scale, and identifies options and needed improvements.

Agronomic uses are already estimated by some suppliers, but the current estimation procedure is likely not standardized. Just as some of the water applied to refill the root zone runs off or percolates, some of the water applied for, say frost control may exceed the minimum needed to accomplish the task. Environmental uses are not generally estimated except as part of a targeted study. Calculations of the Agronomic and Total Beneficial Use Fractions will necessarily be limited and qualified in early implementation years.

The next section includes recommendations for improved data collection and estimation of some water flows in order to support the methodology. However, some data components likely will continue to be difficult to quantify accurately and precisely.

TABLE 5-5
Regional Scale Data Sources and Options
Quantifying the Efficiency of Agricultural Water Use

Data Component	Source or Options	Notes
Crop ET	Regional ET: Method 1: regional-level ETo and Kc	Other optional methods are possible. More than one source available for

TABLE 5-5
Regional Scale Data Sources and Options
Quantifying the Efficiency of Agricultural Water Use

Data Component	Source or Options	Notes
	Method 2: aggregate up from more detailed ETo and Kc Method 3: processed satellite imagery	processed
Applied Water	Surface water from suppliers. Private water rights diversions from SWRCB Groundwater estimated	Use AB1404 reporting as it becomes available GW use is unmeasured. Improved ways to estimate use are needed.
Agronomic Uses	Options: reported by suppliers; estimated by DWR	Is a standard estimation procedure needed? Could address in data assessment phase.
Environmental Uses	Limited studies and estimates available	DWR to work with suppliers, California DWR of Fish and Game and U.S. Fish and Wildlife Service, and other groups to develop estimation procedure.
Recoverable Flows	Estimated as part of the water balance, e.g., total return flows minus estimate of evaporation and flow to salt sinks	Is a standard estimation procedure needed? Could address in data assessment phase.

5.2.3.3 Data Collection Responsibility

DWR recommends that the regional scale efficiency methodology be incorporated into its existing land and water use analysis process conducted by DWR. Most of the data required for the methods are already collected or estimated during this process, and DWR's land and water use analysts have substantial experience and local knowledge needed to implement the methodology effectively. DWR also recommends that the regional scale data collection be coordinated with the data collected and reported by water suppliers, either through their existing reporting processes (e.g., CWC 531.10) or any new data collection associated with supplier-level efficiency methodologies

5.2.3.4 Schedule of Implementation

Implementation of the regional methodology should occur in several phases, extending over a period of xx years. Phasing will allow the use of existing data to prepare initial estimates of the regional methods while data improvements are identified and implemented. A phased approach presents several options to the legislature. First, the entire plan, including all phases, could be authorized and funded. Alternatively, only Phase 1 could initially be authorized and funded, with consideration of Phases 2 and 3 to occur after Phase 1 results and analysis are provided. Finally, Phases 1 and 2 could be authorized, except that the Data Improvement Plan in Phase 2 could be focused more narrowly on pilot tests rather than all identified priorities.

Phase 1: Complete by 2013

- Use existing data and estimates of water use at the regional scales, based on existing hydrologic regions used by the DWR in its planning. This information will be used to calculate the Regional Consumptive Use Fractions and Regional Water Management Fractions, and to the extent possible, the Total Beneficial Use Fraction.
- Characterize the uncertainty of the estimated fractions, and identify the data sources in each region that contribute the greatest amount to the uncertainty.
- Develop a plan to improve the key limiting data in Phase 2.

Phase 2: Complete by 2018

- Based on priorities and available funding, implement the data improvement recommendations from Phase 1. Priorities could be based on data categories or regions of the State.

- Select a region or sub-region as a pilot test to apply the methods using the improved data. Assess results and revise data recommendations if necessary.

Phase 3: Begin after 2018

- Apply improved data collection and estimation processes and implement methods in all regions. Frequency and timing shall be coordinated with analyses done for CWP Updates.

Table 5-6 provides a summary of the implementation plan for the field scale.

TABLE 5-6
Summary of Implementation Plan Elements for Regional Scale Methods
Quantifying the Efficiency of Agricultural Water Use

Implementation Plan Element	Details	Notes
Methods	Regional CUF, Regional Water Management Fraction, Regional Total Beneficial Use Fraction	
Implementing Entities	DWR Land and Water Use analysis units	Coordinate data reporting process with suppliers within region
Data Sources	See Table 5-5	
Schedule and frequency	Initial phase (by 2013): calculate using best existing data and estimates. Identify priorities for improved data. Second phase (by 2018): fund and implement data improvement plan Ongoing after 2018: calculate methods as part of CWP update process, and report with the CWP update (every five years)	Data improvement plan could provide options to the legislature, with associated cost and other implications. Data priorities could include: improved GW estimates, accepted methods and estimates of environmental uses.
Cost	See implementation cost section	

5.2.4 Productivity Indicators

Productivity will be quantified at the county scale and statewide using two indicators: crop production per acre-foot of applied water and the value of crop production per acre-foot of applied water. These are called indicators rather than methods because they do not quantify the economic efficiency of agricultural water use. Rather, they can indicate broad changes or trends over time in the agricultural production and value produced by irrigation (see earlier chapters for the uses and limitations of these indicators). Field scale productivity indicators are only proposed for use by growers at the field scale and are not included in the plan of implementation.

5.2.4.1 Data Collection

The Productivity indicators would be quantified at the county and statewide scale and included in the WPU. The indicators may be calculated on an annual basis if DWR determines that it has sufficient annual water supply data, otherwise the indicators will be calculated for a five-year cycle coincident with the CWP Update.

5.2.4.2 Data Sources, Quality, and Limitations

Crop production and value are reported in County Crop Reports produced by the county agricultural commissioners on an annual basis. The U.S. Department of Agriculture National Agricultural Statistical Service (NASS) also reports production and prices for major commodities. For initial calculations of applied water, DWR will use its estimates from county and DAU level water balances produced for the CWP Update. DWR will also use crop applied water estimates provided by U.C. Cooperative Extension and water suppliers. As improved field-level data become available, these will become the source of both aggregate and crop-specific applied water estimates.

TABLE 5-7
Productivity Data Sources and Options
Quantifying the Efficiency of Agricultural Water Use

Data Component	Source or Options	Notes
Crop production and value	Annual County Crop Reports: USDA NASS reports Optional: local surveys of growers, processers	More than one source may be used
Applied Water	Estimates used in County/DAU water balances. Field-level data as it becomes available	Estimated by DWR land and water use analysts

5.2.4.3 Data Collection Responsibility

DWR will be responsible for collecting all data from existing sources and for compiling and aggregating field-level data up to county and statewide scale as it becomes available from field evaluations.

5.2.4.4 Schedule of Implementation

DWR has already begun providing some of these indicators in its 2009 CWP Update. The county and statewide productivity indicators will be reported in the CWP Update, every five years.

Phase 1: Complete by 2013

- DWR calculates an initial set of indicators for a small number of key crops and reports in the 2013 CWP Update
- DWR develops a priority list of crops for which to calculate the indicators. DWR to consult with the Agricultural Water Management Council and other experts to determine a useful set of comparisons over time and among regions that will inform the public and policy makers. provides a

Phase 2: Complete by 2018

- DWR calculates the indicators according to the priorities developed in Phase 1 and reports in the 2013 CWP Update

TABLE 5-8
Summary of Implementation Plan Elements for Productivity Indicators
Quantifying the Efficiency of Agricultural Water Use

Implementation Plan Element	Details	Notes
Indicators	Productivity of Applied Water Fraction, Value of Applied Water Fraction	
Implementing Entities	DWR economists, with assistance from Land and Water Use analysis units	
Data Sources	See Table 5-7	
Schedule and frequency	Initial phase (by 2013): calculate initial set of indicators. Develop priority list of crops and comparisons. Second phase (2018 and after): calculate and report in CWP updates	Appropriate comparisons over time and across crops or regions should be described and limitations noted.
Cost	See implementation cost section	

5.2.5 Summary of Implementation Plan

5.2.5.1 Roles and responsibilities

5.2.5.2 Schedule and Phasing

Data Limitations

5.3 Estimated Implementation Costs

[This section will discuss the cost of each methodology based on the proposed plan(s) of implementation. It will be made clear that costs will vary by implementation methodology and who will be collecting the data.]

5.3.1 Field Scale

5.3.1.1 Crop Consumptive Use Fraction (CUF)

CUF = ETAW/Applied Water

Data requirements:

ETAW = Total ET of the crop minus effective precipitation for the time scale being evaluated,here effective precipitation is based on accepted professional practices

Applied water = the total water delivered onto the field to grow the crop or meet other agronomic or intentional environmental objectives.

5.3.1.2 Agronomic Beneficial Use Fraction

BUF_A = (ETW + Agronomic needs)/Applied water

Agronomic needs = addition portion of AW directed to help produce the desired agricultural commodity that is not ETAW, where the quantity is determined by accepted professional practices

5.3.1.3 Total Beneficial Use Fraction

5.3.2 Water Supplier Scale

[This section will discuss the cost of implementation of data collection at the various scales, specific to who is collecting the data.]

5.3.3 DWR Hydrologic Region Scale

[This section will discuss the cost of implementation of data collection at the various scales, assuming DWR will do the work or hires consultants to do the work.]

5.3.4 Productivity Indicators

5.3.4.1 Productivity of Applied Water Fraction

[This section will discuss the cost of implementation of productivity of applied water fraction based on data collection at the appropriate scale, county and statewide by DWR]

5.3.4.2 Value of Applied Water Fraction

This proposed indicator measures the value of total crop production in a county per AF of applied water.

[Need to determine if the variable of interest is total crop production or irrigated crop production]

According to Section 2279 of the California Food and Agriculture Code:

> *2279. The commissioner shall compile reports of the condition, acreage, production, and value of the agricultural products in his county. The commissioner may publish such reports, and shall transmit a copy of them to the director.*

Every County Agricultural Commissioner compiles and publishes an Annual Crop and Livestock Report that reports the value of agricultural production in that county. These include estimates, for each significant crop, of harvested acres, average crop yields, and average prices received by the farmers. These County Crop Reports are collected by the DWR. Some staff time would be required to obtain the value of individual and total crop production from the Annual Crop and Livestock Reports and create a spreadsheet for analysis. Additional staff time would be required to disaggregate the value of irrigated agriculture from total crop production for certain crops.

DWR also can produce an estimate of applied water by county.

Table 6-7 summarizes the data acquisition and analysis costs for the Value of Applied water Fraction.

TABLE 6-7
Data Acquisition and Analysis Costs for Value of Applied Water Fractions
Quantifying the Efficiency of Agricultural Water Use

Data Needs	Source	Staff Time (hours per county)	Total Hourly (Cost per county) in dollars	Cost per county in dollars
Value of Total Crop Production	County Agricultural Commissioner	4	98	392
ETAW	DWR Land and Water Use Scientists	20	120	2400
Analyzing data	DWR	1	98	98
Total cost per county				2890
State wide cost				167,620

Glossary (update the definitions)

Agronomic needs = the additional portion of applied water directed to help produce the desired agricultural commodity that is not Evapotranspiration of Applied Water (ETAW), where the quantity is determined using accepted professional practices. Agronomic needs include elements such as; water applied for salinity management, pre-irrigation, frost control, decomposition, and other water applications to the extent that such applications do not exceed what is needed to meet accepted professional practices and are in addition to the water meeting ETAW (e.g. portions of water applied for some agronomic purposes also meet ETAW and would be duplicative in the value included in the numerator).

Applied Water = the total amount of water that is diverted from any source to meet the demands of water users without adjusting for water that is used up, returned to the developed supply or irrecoverable.

Distribution Uniformity= the ability of an irrigation system to deliver water effectively across a field. A typical measure of distribution uniformity is the average depth of water applied to the area of a field receiving the least amount of water divided by the water amount of water applied to a field.

Environmental needs = the portion of applied water directed to environmental purposes within a defined scale, that is not meeting ETAW of the irrigated commodity, including such uses as; water to produce and/or maintain wetland, riparian or terrestrial habitat, where the quantity of water consumed or used for intended objectives is based on accepted professional practices. Applied water associated with a mandated environmental objective but ultimately used for ETAW or agronomic needs in the production of any agricultural commodity would not be characterized as applied water for an environmental need.

Evapotranspiration of Applied Water (ETAW) = Total evapotranspiration of a crop (or crops, if intercropping, cover crops, or multiple crop types are involved) at a defined scale minus estimated quantity of effective precipitation for the time scale being evaluated, where crop ET and effective precipitation are determined using accepted professional practices.

Recoverable Flows = the estimated or measured quantity of water leaving the defined scale as either surface flows or percolation to underlying aquifers. In the instances where the groundwater is actively managed, the recoverable flows would be that portion of groundwater that laterally flows into aquifers outside of the defined regional boundary and/or accretions to rivers.

Gross revenue of crop production = Gross revenue of production of each crop during the time frame, usually one or more production seasons. Gross revenue is the weight of production times the price per unit of weight received by the grower.

Weight of crop production = Total production of each crop during the time frame, usually one or more production seasons, measured in tons or hundredweight.

(Aggregate) *Farm-gate deliveries* = see *Applied Water*

References

Cooley, H; Christian-Smith, Juliet; and Gleick, Peter. 2009. Sustaining California Agriculture in an Uncertain Future. Public Policy Institute of California (PPIC). Oakland, California. July.

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